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TITLE: FERRITIC STAINLESS STEEL SHEET FOR BELLOWS, EXCELLENT IN BELLOWS WORKABILITY AND HIGH TEMPERATURE SALT DAMAGE RESISTANCE

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ABSTRACT:

PROBLEM TO BE SOLVED: To provide an inexpensive ferritic stainless steel for bellows free from expensive Ni and excellent in bellows workability and high temp. salt damage resistance.

SOLUTION: The ferritic stainless steel sheet, which has a composition containing, by weight, ≤0.02% C, 10.0-23.0% Cr, ≤0.015% N, and Ti by the amount in the range between a value ≥4 times the sum of C content and N content and 0.6% and further containing, if necessary, 0.05-2.0% Mo and in which surface roughness is regulated to 0.1-0.5μm by arithmetical mean roughness Ra and to ≤1.50μm by maximum height Rv, is obtained. By this method, the inexpensive bellows material, excellent in bellows workability and high temp. salt damage resistance, can be obtained.

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(71)Applicant : **NIPPON STEEL CORP**
(72)Inventor : **TAKADA TAKESHI**
YAMAMOTO AKIO

(54) FERRITIC STAINLESS STEEL SHEET FOR BELLOWS, EXCELLENT IN BELLOWS WORKABILITY AND HIGH TEMPERATURE SALT DAMAGE RESISTANCE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide an inexpensive ferritic stainless steel for bellows free from expensive Ni and excellent in bellows workability and high temp. salt damage resistance.
SOLUTION: The ferritic stainless steel sheet, which has a composition containing, by weight, ≤0.02% C, 10.0-23.0% Cr, ≤0.015% N, and Ti by the amount in the range between a value ≥4 times the sum of C content and N content and 0.6% and further containing, if necessary, 0.05-2.0% Mo and in which surface roughness is regulated to 0.1-0.5μm by arithmetical mean roughness Ra and to ≤1.5Oμm by maximum height Rv, is obtained. By this method, the inexpensive bellows material, excellent in bellows workability and high temp. salt damage resistance, can be obtained.

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* NOTICES *

CLAIMS

[Claim(s)]

[Claim 1] weight % -- C : 0.02% or less, Cr:10.0-23.0%, and N : 4 or more times of the sum of 0.015% or less, a Ti:C content, and N content -- and ferritic-stainless-steel board for bellows which was excellent in the bellows processability and the elevated-temperature-proof salt damage property that surface roughness is characterized by being 1.50 micrometers or less in 0.1-0.5 micrometers and the maximum depth Rv by arithmetic mean granularity Ra, including 0.6% or less

[Claim 2] The ferritic-stainless-steel board for bellows which was further excellent in the bellows processability and elevated-temperature-proof salt damage property which are characterized by including Mo:0.05-2.0% with weight % at the ferritic stainless steel according to claim 1.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] this invention relates to the ferritic-stainless-steel board for bellows excellent in the bellows processability and elevated-temperature-proof salt damage property which are used for piping of an automobile exhaust air system and gas, and a water pipe.

[0002]

[Description of the Prior Art] The bellows pipe is used for the purpose of absorbing the distortion and vibration by heat as piping, such as a gas and a liquid. Conventionally, the copper alloy and the austenitic stainless steel have been used for this bellows. This reason is because it was difficult with the metal of others [processing / to bellows structure]. That is, a copper alloy and an austenitic stainless steel have the large elongation between the colds, and it is the optimal material for the bellows which applies bulging fabricated by elongation. On the other hand, since ductility ran short, bulging of the metal which consists of a bcc crystal of carbon steel was not completed.

[0003] On the other hand, depending on the corrosive solution passing through the interior, there was a fault that stress corrosion cracking tends to generate the bellows made from an austenitic stainless steel although manufacture is easy. In order to absorb distortion and vibration by bending of the mountain for heights of a pipe, and the valley for a crevice, stress surely applies [this] bellows to a part for a part for heights, and a crevice. That is, removal of stress is impossible structure and parts. Nevertheless, an austenitic stainless steel is the high alloy of stress corrosion crack sensitivity. For this reason, the bellows made from an austenitic stainless steel had the fault of being very easy to generate stress corrosion cracking.

[0004] Then, in order to avoid stress corrosion cracking, it is one of whether it considers as the structure where whether a low material of stress corrosion crack sensitivity being used and the structure, i.e., a stress load, where stress corrosion cracking cannot occur easily structurally do not remain. In order to reduce the stress corrosion crack sensitivity of an austenitic stainless steel, nickel content is made to increase and reducing Cr, N, Mo, and P is proposed as indicated by JP,49-107915,A. However, even if it used such steel, by the time it prevented generating of stress corrosion cracking only by the time to stress-corrosion-cracking generating being extended suitably, it did not result.

[0005] On the other hand, the number of the irregularity of bellows is increased structurally, or it is making angle of bend of a crevice or heights small, and considers reducing the stress which distributes stress and is applied to each crevice or heights. However, since bellows became large or became long, this method had the fault to which cost becomes high -- equipment also has the need of enlarging. And still, it did not cancel but the susceptibility of stress corrosion cracking has been afflicted by stress corrosion cracking depending on environment.

[0006]

[Problem(s) to be Solved by the Invention] As mentioned above, as a bellows material, to the elevated-temperature-proof salt damage property demanded as usability ability in the real environment of another side bellows material although the austenitic stainless steel is excellent in bellows processability, expensive nickel needs to be abundant contained and the rise of a manufacturing cost is imitated, and it is **. Then, this invention is to offer the ferritic stainless steel for bellows which prevented the processing crack at the time of bellows processing of the ferritic stainless steel cheaper than an austenitic stainless steel in cost, and raised yield productivity, and was excellent in the elevated-temperature-proof salt damage property.

[0007]

[Means for Solving the Problem] This invention persons examined by reducing C and N to a limit based on knowledge conventionally, and raising the ductility of a material, in order to improve the ductility of a ferritic stainless steel. However, although the ductility by the tension test of a material improved, fracture accident did not necessarily decrease at the edge of the mountain portion of bellows, or a processing portion. Furthermore, although the influence by inclusion or the sludge was considered and the fracture cross section was observed in detail, it did not come to discover them.

[0008] Then, it noted that the defect on the front face of a material originated, and destruction occurred as causes other than these. In this case, the irregularity on the front face of a material was considered to be the cause. That is, its attention was paid to possibility that stress will concentrate on the portion to which board thickness is small locally with the irregularity on the front face of a material, and fracture will occur. Then, it tried to reduce the processing crack of bellows by stopping the minute irregularity on a front face as much as possible. First, the processability of the same material to which surface roughness was changed was evaluated. Evaluation performed C and N to 0.02 or less % of the weight by the hydrostatic bulge test using the

material reduced as much as possible. The hydrostatic bulge test considered the optimal examination reproducing bellows fabrication, and was used for the evaluation method. Consequently, arithmetic mean granularity Ra and the maximum depth Rv of surface roughness were imagined to be what has influenced the processing crack.

[0009] Then, as a result of repeating examination for the material which consists of various Ra and Rv(s), it found out that Ra excelled [0.1 micrometer or more 0.5 micrometers or less and the maximum depth Rv / material / 1.5 micrometers or less] in processability most. That is, it succeeded in manufacture of the steel plate which can prevent a bellows processing crack by setting Ra and Rv to 0.1 micrometers or more 0.5 micrometers or less and 1.5 micrometers or less, respectively.

[0010] On the other hand, in order to evaluate the elevated-temperature-proof salt damage property of a ferritic stainless steel such low [C and N], the elevated-temperature salt damage cycle examination which simulates the real environment of bellows was performed. an examination -- 3%NaCl solution -- a tabular test piece -- for 5 minutes -- dipping -- the inside of an air furnace -- 500 degrees C -- 2-hour ** -- the examination which made 1 cycle three processes of forced-air cooling for [in the atmosphere] 10 minutes was probably performed up to 5 cycles Although the test-report side after 5 cycles was presenting the general corrosion, the point imagined to be the origin of corrosion was seen in the test piece after 1 cycle. As a result of observing this sample front face in detail, existence of Cr system carbide was accepted in this point. From this, Cr depleted zone of Cr system carbide circumference is the origin of corrosion, and that to which corrosion advances from here to the whole surface was presumed.

[0011] Advance of corrosion will be suppressed if the number of such Cr system carbide is reduced. It thought it effective to make C fix beforehand for that purpose, the steel which made Ti which makes C in steel fix based on knowledge conventionally add was manufactured, and the above-mentioned cycle examination was performed. As a result of measuring the corrosion weight loss of the test piece after 5 cycles, there were few corrosion weight losses of Ti addition steel compared with it of the steel which does not add Ti. Furthermore, as a result of observing the test piece front face after 1 cycle, the origin of corrosion was not able to be found out in Ti addition steel.

[0012] Moreover, the elevated-temperature-proof salt damage property of having excelled further is required of automobile exhaust air system bellows, i.e., the material for flexible tubes. For such a material, more than it reduces the origin of corrosion, it is thought required to suppress advance of a general corrosion as much as possible. Then, under such severe environment, addition of Mo considered conventionally that advance of the general corrosion by elevated-temperature salt damage was effective in suppression by knowledge, the steel which added Mo in addition to Ti was manufactured, and the above-mentioned cycle examination was performed. Consequently, there were very few corrosion weight losses of the test piece after 5 cycles compared with the steel which added only Ti. Thus, it became clear that Ti and Mo addition are effective in the bottom of the salt damage environment where bellows is used.

[0013] this invention is made based on the knowledge of the elevated-temperature-proof salt damage property required of the bottom of the environment where the knowledge and bellows of the processability required of the above bellows processing are used, and is weight %. C : 0.02% or less Cr:10.0-23.0%, N : 0.015% or less, Are 4 or more times of the sum of a Ti:C content and N content, and 0.6% or less is included. Surface roughness is in the ferritic-stainless-steel board for bellows excellent in the bellows processability and elevated-temperature-proof salt damage property which are characterized by being 1.50 micrometers or less in 0.1-0.5 micrometers and the maximum depth Rv by arithmetic mean granularity Ra. Furthermore, in order to bear the bottom of severer bellows elevated-temperature salt damage environment, addition of Mo to the above-mentioned ferritic stainless steel is effective.

[0014]

[Embodiments of the Invention] Below, the reason for limitation of this invention is explained. Although C dissolves to an invaded type and intensity is made to increase, it is the element in which ductility is reduced. Then, in order [being enough] to carry out ductility reservation, the upper limit was made into 0.02% by weight %. Although Cr is the fundamental component of stainless steel, a lot of addition reduces ductility. Then, the upper limit was made into 23% by weight %. The minimum could be 10% in order to secure corrosion resistance. Since N had the same operation as C and it had sufficient ductility for bellows processing, it made the upper limit 0.015% by weight %.

[0015] Ti is a powerful charcoal nitride formation element, and decreases Dissolution C and the amount of N. Consequently, ductility improves. Furthermore, generation of Cr system carbide used as the origin of the corrosion in elevated-temperature salt damage is decreased. Since the addition of Ti needed to make C and N fix completely in stoichiometry as TiC and TiN, it made the minimum 4 times of (C+N) by weight %. However, since it became remarkable ductility falling 0.6% or more of addition according to a dissolution Ti independent, the upper limit was made into 0.6% by weight %.

[0016] Addition of Mo makes advance of a general corrosion suppress. However, superfluous addition degrades the processability of a material and generates the crack at the time of bellows fabrication. Therefore, the minimum of an addition was made into 0.05% and the upper limit was made into 2.0%. About other components, if contained in the usual ferritic stainless steel, there will be no furnace.

[0017] on the other hand -- the steel plate of this invention -- the front face -- arithmetic mean granularity Ra and the maximum depth Rv are specified as a character The value of arithmetic mean granularity Ra and the maximum depth Rv limited with 0.5 micrometers or less, the range, i.e., Ra, with forming height higher than a result of a hydrostatic bulge test, and limited Rv with 1.5 micrometers or less. however -- if Ra is smaller than 0.1 micrometers -- the time of actual bellows processing -- processing -- destruction takes place in the portion which a lubricating oil stops entering between metal mold and a material, and touches metal mold Then, the lower limit of Ra was set up with 0.1 micrometers. The value of Ra and Rv is a value measured based on the test

method of JISB0601. the above-mentioned front face -- a character can be acquired by regulation of the heat treatment temperature for the board temperature regulation in the hot rolling for managing the front face of reduction rolls, such as hot rolling, cold rolling, and skin-pass rolling, proper, and the formation of blemish reduction after the following process, and the still more stable formation of passive state coat formation

[0018] this invention offers the ferritic stainless steel for bellows processing which can decrease the destruction which is easy to generate at the time of processing of bellows. The ferritic stainless steel of a base material becomes possible [securing the difference of the path of the heights of bellows, and a crevice enough] by limiting the content of C and N to low level. Furthermore, it becomes possible by setting Ra to 0.1 micrometers or more 0.5 micrometers or less to decrease and for the lubrication to a lubricating oil with the metal mold at the time of bellows processing to make the stress concentration to the front-face top at the time of processing ease by becoming good and setting Rv to 1.5 micrometers or less on it of the irregularity with an average minute front face. Consequently, the processing crack from which minute irregularity becomes a cause decreases, the crack at the time of bellows processing decreases remarkably, and the yield improves.

[0019] On the other hand, in order to acquire the elevated-temperature-proof salt damage property required of bellows, addition of Ti decreases generating of Cr system carbide used as the origin of corrosion. Furthermore advance of a general corrosion is suppressed by compound addition with Mo, and the ferritic-stainless-steel board for bellows which was excellent in the elevated-temperature salt damage property can be offered.

[0020]

[Example] Hereafter, an example explains this invention steel plate in more detail. First, the various ferritic-stainless-steel boards (0.5mm of board thickness) shown in Table 1 were manufactured at the process of a dissolution-forging-hot-rolling-pickling-cold-rolled-annealing-skin pass by the usual process. the front face which performs the degree of board temperature at the time of hot-rolling, and temperature control at the time of annealing further combining hot-rolling, cold-rolling, and the reduction-roll surface roughness of a skin pass in that case, and is shown in Table 1 -- the character was acquired

[0021] Next, about the obtained various steel plates, the bellows processing examination and the elevated-temperature salt damage cycle examination were carried out, and the test result was shown in Table 2. In addition, those test conditions were as follows.

(1) The hydrostatic bulge test was applied as the evaluation method of simulating a bellows processing examination bellows processing examination. While the examination set the diameter of bulge forming to 100mm and fabricating to a forming height of 28mm, whether a crack occurs or not estimated processability ability. O breaks in Table 2, and generating nothing and x break and show generating.

(2) The elevated-temperature salt damage cycle examination elevated-temperature salt damage cycle examination was dipped in NaCl for 5 minutes 3%, performed three processes of the order of **** and forced-air cooling in the atmosphere for 10 minutes as 1 cycle all over 600-degree-C 2-hour air furnace, and measured the corrosion weight loss after 10 cycles. More than is 5 in n and the average of a corrosion weight loss was calculated. In addition, evaluation of an elevated-temperature salt damage property carried out to the examination on the basis of the corrosion weight loss of present SUS304 steel, using SUS304 steel applied as a present bellows material as a conventional example.

O : -- that a corrosion weight loss is equivalent or less than [it] x: -- there are more corrosion weight losses than SUS304 steel

[0022]

[Table 1]

	鋼成分 (wt.%)					平均粗さ	最大深さ	備考
No	C	Cr	N	Ti	Mo	Ra (μm)	Rv (μm)	
1	0.005	11.10	0.005	0.23		0.3	1.10	本
2	0.015	13.00	0.010	0.08		0.3	1.00	
3	0.005	17.10	0.010	0.20		0.2	1.18	発
4	0.004	12.10	0.006	0.45		0.3	1.30	
5	0.015	17.10	0.010	0.20		0.2	1.27	明
6	0.005	17.00	0.010	0.20	1.0	0.2	1.10	
7	0.002	16.50	0.005	0.15	1.5	0.3	1.41	例
8	0.035	17.10	0.020	0.20		0.2	1.19	比
9	0.010	17.10	0.010	0.05		0.3	1.21	較
10	0.005	18.10	0.012	0.15	3.0	0.3	1.21	例
11	0.020	18.10	0.050			0.3	1.10	比較例 (SUS304)

[0023]
[Table 2]

No	ベローズ加工試験	腐食減量 (mg/cm²)	備考
1	○	○ 4.11	本
2	○	○ 4.39	
3	○	○ 4.13	発
4	○	○ 4.11	
5	○	○ 4.27	明
6	○	○ 3.86	
7	○	○ 3.52	例
8	×	○ 4.22	比
9	×	○ 4.03	較
10	×	○ 4.20	例
11	○	4.46	比較例 (SUS304)

[0024] While the ferritic-stainless-steel board of this invention does not have crack generating by bellows processing and high workability can be borne so that more clearly than Table 2, it excels that an elevated-temperature-proof salt damage property is

also equivalent to present SUS304 steel, or more than it. Especially the thing that carried out compound addition of Ti and the Mo is further excellent in the elevated-temperature-proof salt damage property.

[0025]

[Effect of the Invention] Although bellows processing of a ferritic-stainless-steel board became possible conventionally, and the destruction at the time of manufacture occurred mostly and had caused the rise of a manufacturing cost compared with the austenitic stainless steel, since bellows processability has been improved sharply, with the ferritic-stainless-steel board of this invention, the manufacture yield of bellows improves more greatly than before. Furthermore, since expensive nickel does not need to be included, the effect of cost reduction is also acquired. Moreover, it excels also in an elevated-temperature-proof salt damage property conventionally, and has sufficient corrosion resistance for which the present austenitic stainless steel can be substituted.

[Translation done.]

* NOTICES *

TECHNICAL FIELD

[The technical field to which invention belongs] this invention relates to the ferritic-stainless-steel board for bellows excellent in the bellows processability and elevated-temperature-proof salt damage property which are used for piping of an automobile exhaust air system and gas, and a water pipe.

[Translation done.]

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PRIOR ART

[Description of the Prior Art] The bellows pipe is used for the purpose of absorbing the distortion and vibration by heat as piping, such as a gas and a liquid. Conventionally, the copper alloy and the austenitic stainless steel have been used for this bellows. This reason is because it was difficult with the metal of others [processing / to bellows structure]. That is, a copper alloy and an austenitic stainless steel have the large elongation between the colds, and it is the optimal material for the bellows which applies bulging fabricated by elongation. On the other hand, since ductility ran short, bulging of the metal which consists of a bcc crystal of carbon steel was not completed.

[0003] On the other hand, depending on the corrosive solution passing through the interior, there was a fault that stress corrosion cracking tends to generate the bellows made from an austenitic stainless steel although manufacture is easy. In order to absorb distortion and vibration by bending of the mountain for heights of a pipe, and the valley for a crevice, stress surely applies [this] bellows to a part for a part for heights, and a crevice. That is, removal of stress is impossible structure and parts. Nevertheless, an austenitic stainless steel is the high alloy of stress corrosion crack sensitivity. For this reason, the bellows made from an austenitic stainless steel had the fault of being very easy to generate stress corrosion cracking.

[0004] Then, in order to avoid stress corrosion cracking, it is one of whether it considers as the structure where whether a low material of stress corrosion crack sensitivity being used and the structure, i.e., a stress load, where stress corrosion cracking cannot occur easily structurally do not remain. In order to reduce the stress corrosion crack sensitivity of an austenitic stainless steel, nickel content is made to increase and reducing Cr, N, Mo, and P is proposed as indicated by JP,49-107915,A. However, even if it used such steel, by the time it prevented generating of stress corrosion cracking only by the time to stress-corrosion-cracking generating being extended suitably, it did not result.

[0005] On the other hand, the number of the irregularity of bellows is increased structurally, or it is making angle of bend of a crevice or heights small, and considers reducing the stress which distributes stress and is applied to each crevice or heights. However, since bellows became large or became long, this method had the fault to which cost becomes high -- equipment also has the need of enlarging. And still, it did not cancel but the susceptibility of stress corrosion cracking has been afflicted by stress corrosion cracking depending on environment.

[Translation done.]

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1. This document has been translated by computer.So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3.In the drawings, any words are not translated.

EFFECT OF THE INVENTION

[Effect of the Invention] Although bellows processing of a ferritic-stainless-steel board became possible conventionally, and the destruction at the time of manufacture occurred mostly and had caused the rise of a manufacturing cost compared with the austenitic stainless steel, since bellows processability has been improved sharply, with the ferritic-stainless-steel board of this invention, the manufacture yield of bellows improves more greatly than before. Furthermore, since expensive nickel does not need to be included, the effect of cost reduction is also acquired. Moreover, it excels also in an elevated-temperature-proof salt damage property conventionally, and has sufficient corrosion resistance for which the present austenitic stainless steel can be substituted.

[Translation done.]

MEANS

[Means for Solving the Problem] This invention persons examined by reducing C and N to a limit based on knowledge conventionally, and raising the ductility of a material, in order to improve the ductility of a ferritic stainless steel. However, although the ductility by the tension test of a material improved, fracture accident did not necessarily decrease at the edge of the mountain portion of bellows, or a processing portion. Furthermore, although the influence by inclusion or the sludge was considered and the fracture cross section was observed in detail, it did not come to discover them.

[0008] Then, it noted that the defect on the front face of a material originated, and destruction occurred as causes other than these. In this case, the irregularity on the front face of a material was considered to be the cause. That is, its attention was paid to possibility that stress will concentrate on the portion to which board thickness is small locally with the irregularity on the front face of a material, and fracture will occur. Then, it tried to reduce the processing crack of bellows by stopping the minute irregularity on a front face as much as possible. First, the processability of the same material to which surface roughness was changed was evaluated. Evaluation performed C and N to 0.02 or less % of the weight by the hydrostatic bulge test using the material reduced as much as possible. The hydrostatic bulge test considered the optimal examination reproducing bellows fabrication, and was used for the evaluation method. Consequently, arithmetic mean granularity Ra and the maximum depth Rv of surface roughness were imagined to be what has influenced the processing crack.

[0009] Then, as a result of repeating examination for the material which consists of various Ra and Rv(s), it found out that Ra excelled [0.1 micrometer or more 0.5 micrometers or less and the maximum depth Rv / material / 1.5 micrometers or less] in processability most. That is, it succeeded in manufacture of the steel plate which can prevent a bellows processing crack by setting Ra and Rv to 0.1 micrometers or more 0.5 micrometers or less and 1.5 micrometers or less, respectively.

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[0011] Advance of corrosion will be suppressed if the number of such Cr system carbide is reduced. It thought it effective to make C fix beforehand for that purpose, the steel which made Ti which makes C in steel fix based on knowledge conventionally add was manufactured, and the above-mentioned cycle examination was performed. As a result of measuring the corrosion weight loss of the test piece after 5 cycles, there were few corrosion weight losses of Ti addition steel compared with it of the steel which does not add Ti. Furthermore, as a result of observing the test piece front face after 1 cycle, the origin of corrosion was not able to be found out in Ti addition steel.

[0012] Moreover, the elevated-temperature-proof salt damage property of having excelled further is required of automobile exhaust air system bellows, i.e., the material for flexible tubes. For such a material, more than it reduces the origin of corrosion, it is thought required to suppress advance of a general corrosion as much as possible. Then, under such severe environment, addition of Mo considered conventionally that advance of the general corrosion by elevated-temperature salt damage was effective in suppression by knowledge, the steel which added Mo in addition to Ti was manufactured, and the above-mentioned cycle examination was performed. Consequently, there were very few corrosion weight losses of the test piece after 5 cycles compared with the steel which added only Ti. Thus, it became clear that Ti and Mo addition are effective in the bottom of the salt damage environment where bellows is used.

[0013] this invention is made based on the knowledge of the elevated-temperature-proof salt damage property required of the bottom of the environment where the knowledge and bellows of the processability required of the above bellows processing are used, and is weight %. C : 0.02% or less Cr:10.0-23.0%, N : 0.015% or less, Are 4 or more times of the sum of a Ti:C content and N content, and 0.6% or less is included. Surface roughness is in the ferritic-stainless-steel board for bellows excellent in the bellows processability and elevated-temperature-proof salt damage property which are characterized by being 1.50 micrometers or less in 0.1-0.5 micrometers and the maximum depth Rv by arithmetic mean granularity Ra. Furthermore, in order to bear the bottom of severer bellows elevated-temperature salt damage environment, addition of Mo to the above-mentioned ferritic

stainless steel is effective.

[0014]

[Embodiments of the Invention] Below, the reason for limitation of this invention is explained. Although C dissolves to an invaded type and intensity is made to increase, it is the element in which ductility is reduced. Then, in order [being enough] to carry out ductility reservation, the upper limit was made into 0.02% by weight %. Although Cr is the fundamental component of stainless steel, a lot of addition reduces ductility. Then, the upper limit was made into 23% by weight %. The minimum could be 10% in order to secure corrosion resistance. Since N had the same operation as C and it had sufficient ductility for bellows processing, it made the upper limit 0.015% by weight %.

[0015] Ti is a powerful charcoal nitride formation element, and decreases Dissolution C and the amount of N. Consequently, ductility improves. Furthermore, generation of Cr system carbide used as the origin of the corrosion in elevated-temperature salt damage is decreased. Since the addition of Ti needed to make C and N fix completely in stoichiometry as TiC and TiN, it made the minimum 4 times of (C+N) by weight %. However, since it became remarkable ductility falling 0.6% or more of addition according to a dissolution Ti independent, the upper limit was made into 0.6% by weight %.

[0016] Addition of Mo makes advance of a general corrosion suppress. However, superfluous addition degrades the processability of a material and generates the crack at the time of bellows fabrication. Therefore, the minimum of an addition was made into 0.05% and the upper limit was made into 2.0%. About other components, if contained in the usual ferritic stainless steel, there will be no furnace.

[0017] on the other hand -- the steel plate of this invention -- the front face -- arithmetic mean granularity Ra and the maximum depth Rv are specified as a character The value of arithmetic mean granularity Ra and the maximum depth Rv limited with 0.5 micrometers or less, the range, i.e., Ra, with forming height higher than a result of a hydrostatic bulge test, and limited Rv with 1.5 micrometers or less. however -- if Ra is smaller than 0.1 micrometers -- the time of actual bellows processing -- processing -- destruction takes place in the portion which a lubricating oil stops entering between metal mold and a material, and touches metal mold Then, the lower limit of Ra was set up with 0.1 micrometers. The value of Ra and Rv is a value measured based on the test method of JISB0601. the above-mentioned front face -- a character can be acquired by regulation of the heat treatment temperature for the board temperature regulation in the hot rolling for managing the front face of reduction rolls, such as hot rolling, cold rolling, and skin-pass rolling, proper, and the formation of blemish reduction after the following process, and the still more stable formation of passive state coat formation

[0018] this invention offers the ferritic stainless steel for bellows processing which can decrease the destruction which is easy to generate at the time of processing of bellows. The ferritic stainless steel of a base material becomes possible [securing the difference of the path of the heights of bellows, and a crevice enough] by limiting the content of C and N to low level. Furthermore, it becomes possible by setting Ra to 0.1 micrometers or more 0.5 micrometers or less to decrease and for the lubrication to a lubricating oil with the metal mold at the time of bellows processing to make the stress concentration to the front-face top at the time of processing ease by becoming good and setting Rv to 1.5 micrometers or less on it of the irregularity with an average minute front face. Consequently, the processing crack from which minute irregularity becomes a cause decreases, the crack at the time of bellows processing decreases remarkably, and the yield improves.

[0019] On the other hand, in order to acquire the elevated-temperature-proof salt damage property required of bellows, addition of Ti decreases generating of Cr system carbide used as the origin of corrosion. Furthermore advance of a general corrosion is suppressed by compound addition with Mo, and the ferritic-stainless-steel board for bellows which was excellent in the elevated-temperature salt damage property can be offered.

[Translation done.]

* NOTICES *

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] As mentioned above, as a bellows material, to the elevated-temperature-proof salt damage property demanded as usability ability in the real environment of another side bellows material although the austenitic stainless steel is excellent in bellows processability, expensive nickel needs to be abundant contained and the rise of a manufacturing cost is imitated, and it is **. Then, this invention is to offer the ferritic stainless steel for bellows which prevented the processing crack at the time of bellows processing of the ferritic stainless steel cheaper than an austenitic stainless steel in cost, and raised yield productivity, and was excellent in the elevated-temperature-proof salt damage property.

[Translation done.]

* NOTICES *

EXAMPLE

[Example] Hereafter, an example explains this invention steel plate in more detail. First, the various ferritic-stainless-steel boards (0.5mm of board thickness) shown in Table 1 were manufactured at the process of a dissolution-forging-hot-rolling-pickling-cold-rolled-annealing-skin pass by the usual process. the front face which performs the degree of board temperature at the time of hot-rolling, and temperature control at the time of annealing further combining hot-rolling, cold-rolling, and the reduction-roll surface roughness of a skin pass in that case, and is shown in Table 1 -- the character was acquired

[0021] Next, about the obtained various steel plates, the bellows processing examination and the elevated-temperature salt damage cycle examination were carried out, and the test result was shown in Table 2. In addition, those test conditions were as follows.

(1) The hydrostatic bulge test was applied as the evaluation method of simulating a bellows processing examination bellows processing examination. While the examination set the diameter of bulge forming to 100mm and fabricating to a forming height of 28mm, whether a crack occurs or not estimated processability ability. O breaks in Table 2, and generating nothing and x break and show generating.

(2) The elevated-temperature salt damage cycle examination elevated-temperature salt damage cycle examination was dipped in NaCl for 5 minutes 3%, performed three processes of the order of **** and forced-air cooling in the atmosphere for 10 minutes as 1 cycle all over 600-degree-C 2-hour air furnace, and measured the corrosion weight loss after 10 cycles. More than is 5 in n and the average of a corrosion weight loss was calculated. In addition, evaluation of an elevated-temperature salt damage property carried out to the examination on the basis of the corrosion weight loss of present SUS304 steel, using SUS304 steel applied as a present bellows material as a conventional example.

O : -- that a corrosion weight loss is equivalent or less than [it] x: -- there are more corrosion weight losses than SUS304 steel

[0022]

[Table 1]

	鋼成分 (wt.%)					平均粗さ	最大深さ	備考
No	C	Cr	N	Ti	Mo	Ra (μm)	Rv (μm)	
1	0.005	11.10	0.005	0.23		0.3	1.10	本
2	0.015	13.00	0.010	0.08		0.3	1.00	
3	0.005	17.10	0.010	0.20		0.2	1.18	発
4	0.004	12.10	0.006	0.45		0.3	1.30	
5	0.015	17.10	0.010	0.20		0.2	1.27	明
6	0.005	17.00	0.010	0.20	1.0	0.2	1.10	
7	0.002	16.50	0.005	0.15	1.5	0.3	1.41	例
8	0.035	17.10	0.020	0.20		0.2	1.19	比
9	0.010	17.10	0.010	0.05		0.3	1.21	較
10	0.005	18.10	0.012	0.15	3.0	0.3	1.21	例
11	0.020	18.10	0.050			0.3	1.10	比較例 (SUS304)

[0023]
[Table 2]

No	ベローズ加工試験	腐食減量 (mg/cm²)	備考
1	○	○ 4.11	本
2	○	○ 4.39	
3	○	○ 4.13	発
4	○	○ 4.11	
5	○	○ 4.27	明
6	○	○ 3.86	
7	○	○ 3.52	例
8	×	○ 4.22	比
9	×	○ 4.03	較
10	×	○ 4.20	例
11	○	4.46	比較例 (SUS304)

[0024] While the ferritic-stainless-steel board of this invention does not have crack generating by bellows processing and high workability can be borne so that more clearly than Table 2, it excels that an elevated-temperature-proof salt damage property is

also equivalent to present SUS304 steel, or more than it. Especially the thing that carried out compound addition of Ti and the Mo is further excellent in the elevated-temperature-proof salt damage property.

[Translation done.]

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(54)【発明の名称】　ベローズ加工性および耐高温塩害特性に優れたベローズ用フェライト系ステンレス鋼板

(57)【要約】

【課題】　高価なＮｉを含まない安価で、ベローズ加工性と耐高温塩害特性に優れたベローズ用フェライト系ステンレス鋼を提供する。

【解決手段】　重量％で、Ｃ：０．０２％以下、Ｃｒ：１０．０～２３．０％、Ｎ：０．０１５％以下、Ｔｉ：Ｃ含有量とＮ含有量の和の４倍以上でかつ０．６％以下を含み、さらに必要に応じてＭｏ：０．０５～２．０％を含み、表面粗さが算術平均粗さＲａで０．１～０．５μｍ、かつ最大深さＲｖで１．５０μｍ以下であるフェライト系ステンレス鋼板を得る。これによってベローズ加工性と耐高温塩害特性に優れた安価なベローズ用材料が得られる。

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【特許請求の範囲】

【請求項1】　重量%で、

C　：0．02%以下、

Cr：10．0～23．0%、

N　：0．015%以下、

Ti：C含有量とN含有量の和の4倍以上でかつ0．6%以下を含み、表面粗さが算術平均粗さRaで0．1～0．5μm、かつ最大深さRvで1．50μm以下であることを特徴とするベローズ加工性および耐高温塩害特性に優れたベローズ用フェライト系ステンレス鋼板。

【請求項2】　請求項1記載のフェライト系ステンレス鋼に、さらに重量%で、

Mo：0．05～2．0%

を含むことを特徴とするベローズ加工性および耐高温塩害特性に優れたベローズ用フェライト系ステンレス鋼板。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は自動車排気系、ガスの配管、水道管に使用されるベローズ加工性および耐高温塩害特性に優れたベローズ用フェライト系ステンレス鋼板に関するものである。

【0002】

【従来の技術】ベローズ管は気体、液体等の配管として、熱による歪や振動を吸収するのを目的として使用されている。従来、このベローズには銅合金やオーステナイト系ステンレス鋼が用いられてきた。この理由は、ベローズ構造への加工が他の金属では困難であったためである。すなわち、銅合金やオーステナイト系ステンレス鋼は、冷間での伸びが大きく、伸びによって成形されるバルジ加工を適用するベローズには最適の材料である。これに対して、炭素鋼のbcc結晶からなる金属は延性が不足するためにバルジ加工ができなかった。

【0003】一方、オーステナイト系ステンレス鋼製ベローズは、製造は容易であるものの、内部を通る腐食性の溶液によっては応力腐食割れが発生し易いという欠点があった。これは、ベローズは管の凸部分の山と凹部分の谷の曲げによって歪や振動を吸収するために、凸部分と凹部分には必ず応力が掛かる。すなわち、応力の除去は不可能な構造、部品である。それにもかかわらずオーステナイト系ステンレス鋼は、応力腐食割れ感受性の高い合金である。このため、オーステナイト系ステンレス鋼製のベローズは応力腐食割れが極めて発生し易いという欠点があった。

【0004】そこで、応力腐食割れを回避するためには、応力腐食割れ感受性の低い材料を用いるか、構造的に応力腐食割れが起きにくい構造すなわち応力負荷が残らない構造とするかのどちらかである。オーステナイト系ステンレス鋼の応力腐食割れ感受性を低減するためには、例えば特開昭49－107915号公報に記載されているように、Ni含有量を増加させ、Cr、N、Mo、Pを低減することが提案されている。しかし、このような鋼を用いても応力腐食割れ発生までの時間が相応に伸びるだけで応力腐食割れの発生を防止するまでには至らなかった。

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【0005】一方、構造的にはベローズの凹凸の数を増やしたり凹部や凸部の曲げ角度を小さくすることで、応力を分散してひとつひとつの凹部ないし凸部に掛かる応力を低下させることが考えられている。しかしこの方法は、ベローズが大きくなったり長くなるため装置も大きくする必要があるなど、コストが高くなる欠点があった。しかも、それでも応力腐食割れの感受性は解消せず、環境によっては応力腐食割れに悩まされてきた。

【0006】

【発明が解決しようとする課題】上述したように、ベローズ材料としてオーステナイト系ステンレス鋼はベローズ加工性に優れているが、他方ベローズ材料の実環境での使用性能として要求される耐高温塩害特性に対しては高価なNiの多量含有が必要であり、製造コストの上昇をまねく。そこで、本発明は、オーステナイト系ステンレス鋼よりもコスト的に安価なフェライト系ステンレス鋼のベローズ加工時の加工割れを防止して歩留り生産性を向上させ、かつ耐高温塩害特性に優れたベローズ用フェライト系ステンレス鋼を提供することにある。

【0007】

【課題を解決するための手段】本発明者らは、フェライト系ステンレス鋼の延性を改善するために、従来知見に基づいてCやNを極限まで低減し素材の延性を向上させて試験を行った。ところが、素材の引張試験による延性は向上したにもかかわらず、必ずしもベローズの山部分や加工部分の端部で破断事故は減少しなかった。更に、介在物或いは析出物による影響を考え破断断面を詳細に観察したが、それらを発見するには至らなかった。

【0008】そこで、これら以外の原因として、素材表面の欠陥が起因して破壊が発生することに注目した。この場合、素材表面の凹凸が原因と考えられた。すなわち、素材表面の凹凸により局所的に板厚が小さくなっている部分に応力が集中して破断が発生する可能性に着目した。そこで、表面上の微小な凹凸を極力抑えることで、ベローズの加工割れを低減させることを試みた。まず、表面粗さを変化させた同一素材の加工性を評価した。評価はCおよびNを0．02重量%以下に極力低減させた素材を用いて液圧バルジ試験で行った。液圧バルジ試験はベローズ成形を再現する最適な試験と考え評価方法に用いた。その結果、表面粗さの算術平均粗さRaおよび最大深さRvが加工割れに影響しているものと推察された。

【0009】そこで、種々のRaおよびRvからなる素材で検討を重ねた結果、Raが0．1μm以上0．5μm以下かつ最大深さRvが1．5μm以下の素材が最も

加工性に優れていることを見出した。すなわち．Ｒａ、Ｒｖをそれぞれ０．１μｍ以上０．５μｍ以下．１．５μｍ以下にすることでベローズ加工割れを阻止できる鋼板の製造に成功した。

【００１０】一方、この様な低ＣおよびＮのフェライト系ステンレス鋼の耐高温塩害特性を評価するために、ベローズの実環境を模擬する高温塩害サイクル試験を行った。試験は、３％ＮａＣｌ水溶液に板状試験片を５分間浸し．大気炉中５００℃で２時間保定し、大気中１０分間の強制空冷の３工程を１サイクルとした試験を５サイクルまで行った。５サイクル後の試験表面は全面腐食を呈していたが．１サイクル後の試験片では腐食の起点と推察される点が見られた。この試料表面を詳細に観察した結果、この点にＣｒ系炭化物の存在が認められた。このことより、Ｃｒ系炭化物周辺のＣｒ欠乏領域が腐食の起点であり、ここから全面に腐食が進行するものと推定された。

【００１１】この様なＣｒ系炭化物の数を低減させれば腐食の進行は抑制される。そのためにはＣを予め固着させることが有効であると考え、従来知見に基づき鋼中のＣを固着させるＴｉを添加させた鋼を製造し上記のサイクル試験を行った。５サイクル後の試験片の腐食減量を測定した結果．Ｔｉ添加鋼の腐食減量はＴｉを添加しない鋼のそれに比べ少なかった。さらに．１サイクル後の試験片表面を観察した結果．Ｔｉ添加鋼では腐食の起点は見出せなかった。

【００１２】また、自動車排気系ベローズすなわちフレキシブルチューブ用素材には更に優れた耐高温塩害特性が要求される。この様な素材では腐食の起点を低減させる以上に極力全面腐食の進行を抑制することが必要と考えられる。そこで、この様な厳しい環境下では従来知見によりＭｏの添加が高温塩害による全面腐食の進行を抑制に有効であると考え、Ｔｉに加えＭｏを添加した鋼を製造し、上記のサイクル試験を行った。その結果．５サイクル後の試験片の腐食減量はＴｉのみ添加した鋼に比べ極めて少なかった。この様にして．ベローズが使用される塩害環境下においても．Ｔｉ、Ｍｏ添加は有効であることが判明した。

【００１３】本発明は、以上のベローズ加工に要求される加工性の知見とベローズが使用される環境下に要求される耐高温塩害特性の知見を基になされたものであって．重量％で．Ｃ　：０．０２％以下．　Ｃｒ：１０．０～２３．０％．Ｎ　：０．０１５％以下、Ｔｉ：Ｃ含有量とＮ含有量の和の４倍以上でかつ０．６％以下を含み．表面粗さが算術平均粗さＲａで０．１～０．５μｍ．かつ最大深さＲｖで１．５０μｍ以下であることを特徴とするベローズ加工性および耐高温塩害特性に優れたベローズ用フェライト系ステンレス鋼板にある．さらに．より厳しいベローズ高温塩害環境下に耐えるためには．上記フェライト系ステンレス鋼へのＭｏの添加が有効である。

【００１４】

【発明の実施の形態】以下に、本発明の限定理由について説明する。Ｃは侵入型に固溶して強度を増加させるが．延性を低下させる元素である。そこで十分な延性確保するために．上限を重量％で０．０２％とした．Ｃｒはステンレス鋼の基本成分であるが．多量の添加は延性を低下させる．そこで上限を重量％で２３％とした。下限は．耐食性を確保するため１０％とした。Ｎは．Ｃと同様の作用を有するので．ベローズ加工に十分な延性を有するため、上限を重量％で０．０１５％とした。

【００１５】Ｔｉは、強力な炭窒化物形成元素であり、固溶Ｃ、Ｎ量を減少させる．その結果．延性は向上する．さらに、高温塩害における腐食の起点となるＣｒ系炭化物の生成を減少させる．Ｔｉの添加量はＴｉＣおよびＴｉＮとしてＣおよびＮを量論的に完全に固定させる必要があるので．重量％で下限を（Ｃ＋Ｎ）の４倍とした．しかし、０．６％以上の添加は固溶Ｔｉ単独による延性低下が顕著となるので．上限を重量％で０．６％とした。

【００１６】Ｍｏの添加は．全面腐食の進行を抑制させる．しかし、過剰の添加は素材の加工性を劣化させてベローズ成形時の割れを発生させる。そのため、添加量の下限を０．０５％とし、上限を２．０％とした。その他の成分については、通常のフェライト系ステンレス鋼に含有されるものであればかまはない。

【００１７】一方、本発明の鋼板は．その表面性状として算術平均粗さＲａと最大深さＲｖを規定する。算術平均粗さＲａおよび最大深さＲｖの値は．液圧バルジ試験の結果より、成形高さの高い範囲すなわちＲａを０．５μｍ以下、かつＲｖを１．５μｍ以下と限定した。しかし．Ｒａが０．１μｍより小さいと．実際のベローズ加工時に加工金型と素材の間に潤滑油が入らなくなり、金型と接触している部分で破壊が起こる。そこで．Ｒａの下限値を０．１μｍと設定した。ＲａおよびＲｖの値は．ＪＩＳＢ０６０１の試験方法に準拠して測定した値である。上記表面性状は．熱間圧延．冷間圧延．スキンパス圧延等の圧延ロールの表面を適正に管理すること、また次工程以降の得低減化のための熱間圧延における板温調節、更には安定な不動態皮膜形成化のための熱処理温度の調節により得ることが出来る。

【００１８】本発明は、ベローズの加工時に発生し易い破壊を減少し得るベローズ加工用のフェライト系ステンレス鋼を提供する。母材のフェライト系ステンレス鋼は．ＣおよびＮの含有量を低いレベルに限定することによって、ベローズの凸部と凹部の径の差を十分確保することが可能となる。更に．Ｒａを０．１μｍ以上０．５μｍ以下にすることで、平均的な表面の微小な凹凸は減少し．かつベローズ加工時の金型との潤滑油による潤滑が良好になり．その上でＲｖを１．５μｍ以下にするこ

とで加工時の表面上への応力集中を緩和させることが可能となる。この結果、微小な凹凸が原因となる加工割れが低減し、ベローズ加工時の割れは著しく減少して歩留りは向上する。

【0019】一方、ベローズに要求される耐高温塩害特性を得るために、Tiの添加は腐食の起点となるCr系炭化物の発生を減少させる。さらにMoとの複合添加により全面腐食の進行が抑制され、高温塩害特性の優れたベローズ用フェライト系ステンレス鋼板が提供できる。

【0020】

【実施例】以下、本発明鋼板を実施例でさらに詳しく説明する。まず、表1に示す各種フェライト系ステンレス鋼板（板厚0．5mm）を、通常の製法によって、溶解－鋳造－熱延－酸洗－冷延－焼鈍－スキンパスの工程で製造した。その際に、熱延、冷延、スキンパスの圧延ロール表面粗度を組み合わせて、さらに熱延時の板温度および焼鈍時の温度調節を行い表1に示す表面性状を得た。

【0021】次に、得られた各種鋼板について、ベローズ加工試験および高温塩害サイクル試験を実施し、試験結果を表2に示した。なお、それらの試験条件は以下の＊20＊通りであった。

（1）ベローズ加工試験

ベローズ加工試験をシミュレートする評価方法として液圧バルジ試験を適用した。試験は、バルジ成形の直径を100mmとし、成形高さ28mmまで成形する間に割れが発生するか否かによって加工性能を評価した。表2で○は割れ発生なし、×は割れ発生を示す。

（2）高温塩害サイクル試験

高温塩害サイクル試験は、3%NaCl に5分間浸し、600℃2時間大気炉中に保定、10分間の大気中強制空冷の順の3工程を1サイクルとして行い、10サイクル後の腐食減量を測定した。n数は5であり、腐食減量の平均値を求めた。なお、試験には現行のベローズ材料として適用されているSUS304鋼を従来例として用い、高温塩害特性の評価は現行SUS304鋼の腐食減量を基準として行った。

○：腐食減量が同等またはそれ以下

×：腐食減量がSUS304鋼より多い

【0022】

【表1】

	鋼成分（wt.%）					平均粗さ	最大深さ	備考
No	C	Cr	N	Ti	Mo	Ra (μm)	Ry (μm)	
1	0.005	11.10	0.005	0.23		0.3	1.10	本
2	0.015	13.00	0.010	0.08		0.3	1.00	
3	0.005	17.10	0.010	0.20		0.2	1.18	発
4	0.004	12.10	0.008	0.45		0.3	1.30	
5	0.015	17.10	0.010	0.20		0.2	1.27	明
6	0.005	17.00	0.010	0.20	1.0	0.2	1.10	
7	0.002	16.50	0.005	0.15	1.5	0.3	1.41	例
8	0.035	17.10	0.020	0.20		0.2	1.19	比
9	0.010	17.10	0.010	0.05		0.3	1.21	較
10	0.005	18.10	0.012	0.15	3.0	0.3	1.21	例
11	0.020	18.00	0.050			0.3	1.10	比較例（SUS304）

【0023】

【表2】

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No.	ベローズ加工試験	腐食減量 (mg/cm²)	備考
1	○	○ 4.11	本
2	○	○ 4.39	
3	○	○ 4.13	発
4	○	○ 4.11	
5	○	○ 4.27	明
6	○	○ 3.86	
7	○	○ 3.52	例
8	×	○ 4.22	比
9	×	○ 4.03	較
10	×	○ 4.20	例
11	○	4.46	比較例 (SUS304)

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【００２４】表２より明らかなように、本発明のフェライト系ステンレス鋼板はベローズ加工による割れ発生がなく高加工度に耐えられると同時に、耐高温塩害特性も現行ＳＵＳ３０４鋼と同等またはそれ以上に優れている。特に、ＴｉとＭｏを複合添加したものは、耐高温塩害特性がさらに優れている。

【００２５】

【発明の効果】従来、フェライト系ステンレス鋼板のベローズ加工は可能となったものの、オーステナイト系ステンレス鋼に比べると製造時の破壊が多く発生し、製造コストの上昇を招いていたが、本発明のフェライト系ステンレス鋼板ではベローズ加工性を大幅に改善されたので、ベローズの製造歩留まりが従来よりも大きく向上する。さらには、高価なＮｉを含まなくてもよいのでコスト低減の効果も得られる。また、従来よりも耐高温塩害特性にも優れ、現行のオーステナイト系ステンレス鋼に代替しうる十分な耐食性を有している。